# Leslie Model-based Population Forecast of Henan Province under the Universal Two-child Policy

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**Abstract.** In recent years, in order to alleviate the social aging problems and enlarge the newborn population, China has gradually adjusted the fertility policy to the Universal Two-child Policy. Future population development in China has also become the focus of a lot of studies. This paper uses the 2010 census data and the Henan Yearbook statistics to revise the fertility parameters in Leslie population forecasting model considering the Universal Two-child Policy. This paper adopts both the original model and the revised one to do the prediction of the future population of Henan Province, and compares the results as to the population development trend and population structure change. Using the revised Leslie model to make population prediction, we can better provide an objective basis for improving social education, employment, pension and other policy adjustment.

**Keywords:** The Universal Two-child Policy; Leslie Population Forecast Model; Population Size; Population Structure.

## 1. Introduction

Since the 1970s, in order to control the rapid population growth, improve the quality of the population and alleviate the population pressure on the resources and environment, China implemented the family planning policy and identified it as a basic national policy. With the implementation of family planning policy, China's population growth situation has undergone significant changes. However, the family planning policy has also brought about the aging of the population, gender imbalance and many other social problems. In response to the current population situation, the Communist Party of China put forward the selective two-child policy in November 2013 and put forward another population policy adjustment "the full implementation of a couple can have two children policy" in October 2015. The universal two-child policy on China's future population situation has become the focus of attention of the community.

About researches on population situation in China, Li predicted the impact of The Selective Two-child Policy on China's population growth and population structure by establishing a queue element prediction model, and the study showed that the adjustment of reproductive policy can moderately improve China's low population birth rate, deepening the issues such as population aging in 2015 [1]. In 2016, Xiang used the age shift algorithm to predict the number of births in Hubei Province from 2016 to 2020 under the Universal Two-child Policy background. The results show that the initial implementation of the policy will bring about rebounds in the births number, and then will decline year by year, so the policy cannot effectively change the overall situation of population development [2]. At the same time, many scholars have also studied the change in the fertility willingness of the family and the women of childbearing age caused by the fertility policy adjustment. In 2014, Shi's research result showed that the development level of urban and rural areas, the women age and the educational level had a stronger impact on family fertility. Wang analyzed the data of Zhengzhou City to examined women's fertility intention influence factors under the background of the Universal Two-child Policy. It was found that women aged at 35-40 years had a higher fertility expectation, while occupational and family factors had a higher impact on fertility [3]. In 2017, based on the differences between urban and rural areas, Jin analyzed the Qingdao women of childbearing age's fertility and their evaluation of the Universal Two-child Policy [4]. In recent years, there are many researches on population forecasting at home and abroad, which provides a more objective reference for the formulation of population policies in different regions, such as logistic model, BP neural network model, Leslie population forecast model and so on[5-8].

Henan Province, as one of the most populous provinces in China, has a large population base. Through the investigation of the current population situation, its future population quantity and development trend can be predicted. Because the Leslie model takes into account most of the factors that affect the population, it is a more accurate predictive method. Therefore, this paper utilizes the sixth census data in 2010 combined with the Henan Statistical Yearbook to establish the Leslie population forecast model. And the impact of the Universal Two-child Policy is considered in terms of the fertility of women, so the Leslie model parameters are revised. The prediction is expected to play a practical role in the promotion of the balanced population development. The study can provide objective evidence for the rational formulation of policies such as social education, employment and pension as well.

## 2. Construction and Parameters Revision of Leslie Population Prediction Model in Henan Province under the Universal Two-Child Policy

### 2.1 Leslie Model Assumptions and Variable Descriptions

Leslie model is a model to predict the trend of population change in a region according to the age group and the number of women of childbearing age and the fertility rate. First of all, some assumptions of the model are described as follows: (1) the maximum age of the population is 100 years; (2) the impact of population migration is not taken into account; (3) the fertility rate, birth rate and mortality rate of each age group in the forecast period are stable; (4) the fertility policy is unchanged during the forecast period; (5) the gender proportion of newborns is at a natural ratio.

Some of the variables in the model are described as follows:

(1) Age groups. According to the different fertility rates of different age groups, the population can be grouped by age. Set an age group every 5 years, and then the age is divided into 20 sections, with the symbol i, i = 1, 2, ... , 20, where age group 1 stands for age range 0-4, 2 stands for 5-9, and so on.

(2) Time division. The observation interval is set to be consistent with the age interval, that is, every 5 years as a time interval, with the symbol t, t = 0,1,2, .... Where 0 stands for 2015, 1 stands for 2020, and so on.

(3) The total population matrix. During the t period, the total number of people in the i age group is Ni(t) (i=1,2,…,20), and the total population number in the period t is denoted by N(t)=[ N1(t), N2(t),…, N20(t)]T.

(4) Fertility rates. The fertility rate is the average number of children born in the i age group per unit time. That is, the fertility rate of the i age group is expressed in bi (i=1, 2,…, 20). According to the statistics of the National Bureau of Statistics, the age range of women of childbearing age is 15-49 years old, that is, b1=b2=b3=b11=…=b20=0.

(5) Mortality. The mortality rate refers to the ratio of the number of female deaths in the i age group to the total number of women in the group. The mortality rate in the i age group is expressed as di (i=1, 2,…, 20), and the female survival rate si in the i age group can be expressed as si, si=1-di (i=1, 2,…, 20).

(6) The female population ratio. The ratio of the total number of women of childbearing age in i age group to the total age of the age group is expressed by Ki (i=1, 2,…, 20). From the data of the National Bureau of Statistics, k1=k2=k3=k11=…=k20=0.

(7) The revised fertility rate. Because the Universal Two-child Policy has an impact on the fertility rate, the revised fertility rate is expressed in Bi after the implementation of the Universal Two-child Policy.

### 2.2 Construction of Leslie Model for Henan Population Forecast

Using Leslie model, the relationship is established. In the i age group, the fertility rate bi, the survival rate si, the total population Ni(t) during t period, and the total population Ni(t+1) during t+1

period can establish the following relationships, which only consider the effects of fertility rate, sex ratio and mortality on the total population:

$$\begin{aligned} \mathrm{N}_{\mathrm{i}}(t+1) &= \sum_{i=1}^{20} b_i N_i(t) \\ \mathrm{N}_{\mathrm{i+1}}(t+1) &= s_i N_i(t), (i = 1, 2, ..., 20) \end{aligned} \tag{1}$$

As a matrix

$$L = \begin{bmatrix} 5b_1 & 5b_2 & ... & 5b_{19} & 5b_{20} \\ s_1 & 0 & ... & 0 & 0 \\ 0 & s_2 & ... & 0 & 0 \\ ... & ... & ... & ... & ... \\ 0 & 0 & ... & s_{19} & 0 \end{bmatrix} \tag{2}$$

Then (1) can be written as

$$N(t+1) = LN(t), (t = 0, 1, 2...) \tag{3}$$

When L and N (0) are known, then for any t, there is

$$N(t) = L' N(t), (t = 0, 1, 2...) \tag{4}$$

From the parameter assumptions, a time interval can be set as every 5 years, and the total number of population in the t time period can be obtained from National Bureau of Statistics of the People's Republic of China, and then using the survival rate si=1-di, the number of survivors in the t + 1 time period can be predicted:

$$N_{\mathrm{i+1}}(t+1) = (1 - d_i)^5 N_i(t), (i = 1, 2, ..., 20) \tag{5}$$

At the same time, since the number of the zero age population in the second year is produced from the previous year's women of childbearing age, so the number of infants born in five years should be counted in the 0-4 age group. According to the proportion of women of childbearing age in each age group, the population of 0-4 age group is:

$$\mathrm{N}_{\mathrm{i}}(t) = 5K_i \sum_{i=1}^{20} b_i N_i(t), (i = 1, 2, ..., 20) \tag{6}$$

According to The data of the sixth census in Henan Province in 2010, the population of Henan Province is predicted to be 95.18 million in 2015, and the error rate is 4 ‰ compared with the actual population of 94.8 million. Therefore, it can be considered that the model is suitable for population forecast in Henan Province. But the original Leslie model depends on the total fertility rate for population projection, so the forecast results are prone to be biased when the policy is changed. Thus it is necessary to add the Universal Two-child Policy as an influencing factor to the original Leslie model and to analyze the effects of several factors on the fertility rate.

### 2.3 Fertility Parameter Revision of Leslie Population Prediction Model under the Universal Two-child Policy

1) Estimation of optimized fertility rate

At present, the fertility rate in China is mainly composed of the fertility rate of the first child fertility rate, the second child fertility rate and the third child fertility rate, while the fertility rate of the urban and rural women of childbearing age is different, so the fertility rate parameter should be revised according to these characteristics. Define the urbanization rate of Henan Province as Y. The

first child fertility rate is expressed by $B_{i1}^{c}$; the second child fertility rate is denoted by $B_{i2}^{c}$; the third child fertility rate is denoted by $B_{i3}^{c}$; where c = 1 indicates the town, c = 2 represents the village. The optimized total fertility rate is expressed by B. The formula is:

$$B = 5[Y\sum_{i=4}^{10}(B_{i1}^{1} + B_{i2}^{1} + B_{i3}^{1}) + (1-Y)\sum_{i=4}^{10}(B_{i1}^{2} + B_{i2}^{2} + B_{i3}^{2})] \tag{7}$$

The revised fertility parameters are substituted for the fertility parameters in the original Leslie model. The Leslie model of revised parameters formula is:

$$\begin{cases} N_{i+1}(t+1) = (1-d_i)^5 N_i(t), (i = 1,2,...,20) \\ \mathrm{N_i}(t) = 5K_i[Y\sum_{i=4}^{10}(B_{i1}^{1} + B_{i2}^{1} + B_{i3}^{1})N_i(t) + \\ (1-Y)\sum_{i=4}^{10}(B_{i1}^{2} + B_{i2}^{2} + B_{i3}^{2})N_i(t)], (i = 1,2,...,20) \end{cases} \tag{8}$$

2) Forecast of urban and rural population migration

Because the urban fertility rate is different from the rural one, the urbanization rate will have a certain impact on the population fertility level in the region. With the urbanization data released by the Henan Yearbook 2015, this paper uses the Logistic model to forecast the future development trend of urbanization in Henan Province. The formula for the Logistic model is:

$$\mathrm{Y}=\frac{\mathrm{A}}{1+\mathrm{ae}^{bt}} \tag{9}$$

In (9) where Y is the level of urbanization, and A is the upper limit of urbanization development, which is set to 80 because of the inverse phenomenon of urbanization. And a represents the integral constant, b represents the growth parameter, and t represents the time.

Let $a = A*c$, $b = \ln d$. There is $\mathrm{Y}=\frac{\mathrm{A}}{1+\mathrm{Ace}^{t\ln d}}$, where c is the constant in the regression result, and d is the coefficient.

Under the Logistic curve estimation in SPSS software, the parameter values c, d are output. The model equation is:

$$\mathrm{Y}=\frac{80}{1+74.16\mathrm{e}^{t\ln 0.927}} \tag{10}$$

According to (10), we can calculate the urbanization rate of Henan Province from 2015 to 2050 (see Table I).

3) Prediction of second child fertility rate of women of childbearing age in each age group

After the implementation of the Universal Two-child Policy, the policy has mainly affected the fertility rate of the second child. Study of fertility intention of women of childbearing age in Henan Province shows that women aged at 35-40 have a strong desire to have two children, namely almost 100%. Thus, this paper assumes that women aged at 35-40 who have had one child intend to have the second birth, while fertility rates remain unchanged for women of childbearing age at other ages.

Table 1. Forecast Results of Urbanization Rate in Henan Province

| Year | Urbanization (%) | Year | Urbanization (%) |
|---|---|---|---|
| 2015 | 46.11 | 2035 | 68.96 |
| 2020 | 53.25 | 2040 | 72.11 |
| 2025 | 59.56 | 2045 | 74.44 |
| 2030 | 64.81 | 2050 | 76.11 |

# 3. Application of Leslie Population Forecast Model in Henan Province with Revised Parameters

## 3.1 The Solution of the Leslie Population Forecast Model in Henan Province based on the Revised Parameters

Using the above parameter-revised Leslie model with the relevant demographic indicators and age groups and fertility rates data (see Table II) in 2015 Henan Province, we can calculate the future population, the number of population and population structure. According to the relationship between urban and rural fertility rates and the fertility rate in Henan province in the sixth census in 2010 and related assumptions, urban fertility and rural fertility in Henan Province in 2015 could be estimated. With substituting of data in Table II into the formula (8), we can get the results shown in Fig. 1.

Table 2. Age Groups and Fertility Rates for Henan Province in 2015

| Age Range | Fertility Rate(‰) | First Child Fertility Rate | Second Child Fertility Rate | Third Child Fertility Rate |
|---|---|---|---|---|
| 15-19 | 6.85 | 6.08 | 0.74 | 0.02 |
| 20-24 | 69.98 | 49.01 | 19.49 | 1.48 |
| 25-29 | 76.69 | 37.85 | 34.15 | 4.68 |
| 30-34 | 42.29 | 12.53 | 22.91 | 6.84 |
| 35-39 | 19.21 | 3.56 | 10.45 | 5.21 |
| 40—44 | 6.7 | 1.6 | 3.52 | 1.57 |
| 45—49 | 3.84 | 1.06 | 1.81 | 0.97 |

It can be seen from Fig. 1, after the implementation of the universal two-child policy, 0-5 year-old population compared to the original fertility policy has a greater increase. The proportion of young people is also growing, and in a certain period of time tends to maintain a relatively stable state. Since the number of newborn birth increases, the proportion of aging population is gradually weakened and ultimately will remain at a relatively stable rate.

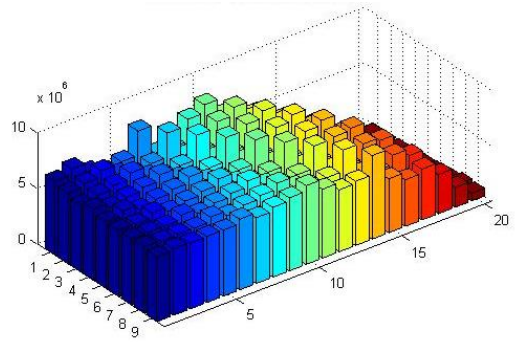



Figure 1. Population prediction for each phases of 2015-2050

## 3.2 Analysis on the Changing Trend of Population Situation in Henan Province before and after the Adjustment of Fertility Policy

According to the parameter-revised Leslie model, the results of the population change in Henan Province from 2015 to 2055 are shown in Fig. 1. It can be seen from the figure that although China has adjusted the fertility policy, that is, implementing the Universal Two-child Policy, still the number of births tends to gradually reduce. But compared with the number of births before the implementation of the Universal Two-child Policy, the policy can effectively increase the birth population and delay the decline of the birth population.

Under the influence of the policy, with the increase of urban and rural fertility rates and the higher intention of giving birth of the second child for women of 35-39, the total population size of Henan Province is expected to reach the peak in 2040 if fertility intention is given full play. Then the total population size will fall, gradually get reduced, and finally keep stabilized.

The forecast results of the number of future populations in Henan Province predicted by the Leslie model were compared with those which was predicted by the parameter revised Leslie model under the universal two-child policy. The results are shown in Fig. 2, where we can see the universal two-child policy can effectively alleviate the rapid decline in population size in Henan Province. And then, Fig. 3(a) and Fig. 3(b), respectively, give the trend of population structure in Henan Province under the Universal Two-child Policy. It can be seen that the proportion of juvenile population declines significantly when the fertility policy is not adjusted, and the rate of decline in the proportion of juvenile population has slowed significantly after the implementation of the Universal Two-child Policy, while the rate of increase in the proportion of the elderly population has also slowed down.

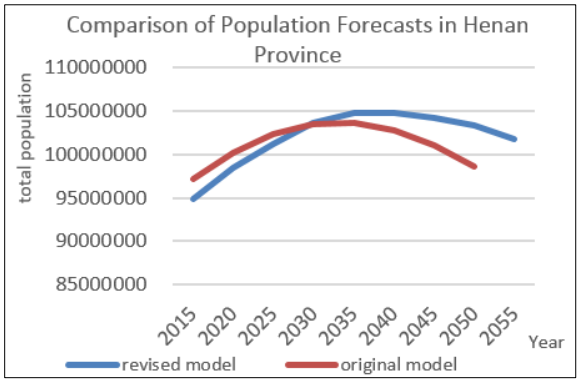
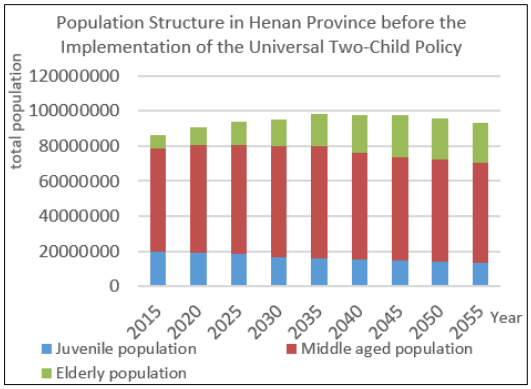



Figure 2. Comparison of population forecasts



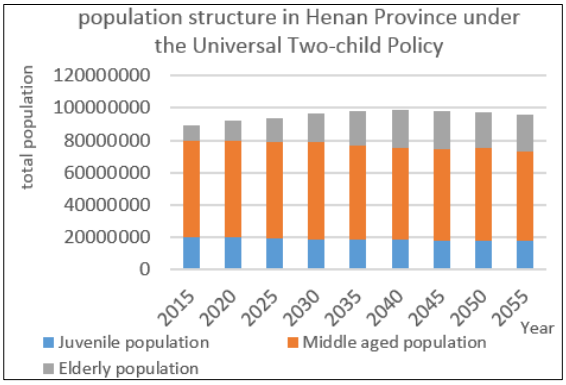




Figure 3(a) and 3(b). Comparison of population structure before and after policy

## 4. Summary

First of all, this paper compares the forecast data with the actual population data to verify the Leslie population forecasting model's applicability in Henan Province. Secondly, this paper focuses on the Universal Two-child Policy, discusses the impact of the urbanization rate to fertility of women and the new fertility policy on the population size and population structure in Henan Province. Finally, by comparing the trend of population changes in Henan Province before and after the adjustment of the fertility policy, the paper points out that the Universal Two-child Policy will lead to the increase of the fertility rate of the second child and the increase of the number of births in a certain period of time. And then the effect of policy impact will be gradually weaken.

At the same time, due to the fact that the actual fertility intention and fertility behavior are often not exactly matched, there may be a high estimate of the change in the fertility rate of the second child. Therefore, the population aging in Henan Province is still serious. And from fertility changes to the population changes is also a long process, so the universal two-child policy should not be the end of the reproductive policy adjustment. We should make reference to the policy adjustment of other countries with a similar history of population development in China, and make the decision to adjust the fertility policy in time to meet the needs of social and life development.

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